Abstract
The concealment procedure used by CELP speech decoders to regenerate lost frames introduces an error that propagates into the following frames. Within the context of voice transmission over packet networks, some packets arrive too late to be decoded and must also be concealed. Once they arrive however, those packets can be used to update the internal state of the decoder, which stops error propagation. Yet, care must be taken to ensure a smooth transition between the concealed frame and the following “updated” frame computed with properly updated internal states. During voiced or quasi-periodic segments, the pitch phase error that is generally introduced by the concealment procedure makes it difficult and detrimental to quality to use the traditional fade-in, fade-out approach. This paper presents a method to handle that pitch phase error. Specifically, the transition is done in such a way that the natural pitch periodicity of the speech signal is not broken.

Problems and Goals
- Understand effects of lost frames on the decoder
  How much does updating with late frames improve this?
- Examine shortcomings of using late frames
  Where are problems encountered during recovery?
- Fix pitch phase error introduced by concealment

Lost and Late Frames
A - Normal decoding, no losses
B - Frame n lost
C - Frame n late, fade-in fade-out window during frame n+1

But...the fade-in, fade-out window does not always work!
- Sometimes summing the two signals creates an artifact

Notice the loss of energy after frame 2 is late

Resynchronization
- For periodic signals, distance between pulses is the period
- Concealment in frame 2 introduces pitch phase error
  - Double pulse from sum of A and B in recovery frame

Resynchronization repairs the pitch-phase error

Internal State Updating
Updating Reduces Error Propagation
A - Original speech signal
B - 3rd frame lost
C - 3rd frame late, updated
D, E - Error signals for B, C respectively

Excitation Domain
- Close-up of recovery frame
- Find the first full pulse, in A
- Find offset, \( \delta \), between A and B using cross-correlation
- Find minimum energy point, \( \mu \), in A
- Merge A and B at \( \mu \) to form C
- Decoder with variable frame lengths is necessary

Pitch periodicity is maintained and the double pulse in D is eliminated

Conclusion
- Concealment causes a pitch-phase error
- This error is noticeable in the transition after a late voiced frame
- Resynchronizing concealed and updated signals fixes this error.
- Error occurs rarely, audio samples on request